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MONTANA'S NATURAL RESOURCES

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Placer Mining, Jefferson Bar, August 1890

Montana Historical Society, Helena

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Stake out your claim. Go
downwards. Bore Through the
tough crust. Oh learn
To feel
A way in darkness to good ore.
—Cecil Day Lewis

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Oct 9, 1995
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It's not surprising that the state seal of Montana has a miner's pick and shovel and the Spanish words "oro y plata" (gold and silver) on it. Montana has large amounts of these minerals, and many others as well. Mining was the first true industry in the state, and although the gold rush days are far behind us, mining and minerals are still important in our economy.

When we talk about minerals, it's useful to have a definition of what they are: A mineral is an inorganic (that is, nonliving) substance that has a definite chemical composition and a particular arrangement of atoms. Each mineral has its own chemical code or formula that tells you which elements it contains, and in what proportions. For example, corundum, or aluminum oxide, has a formula of Al_2O_3, meaning that for every two atoms of aluminum it has three atoms of oxygen.

To understand why Montana is so rich in this natural resource, you need to know something about our state's geological history. First, suppose you could drive west across Montana on the "High Line" from Wolf Point to Havre, then south to Great Falls, down to Helena, and across the Continental Divide to Butte. All along the way you would see signs left by events that occurred in Montana's geologic past. You'd see canyons and valleys carved by streams and rivers. You'd see horizontal lines high above the valleys on the hills east of the divide, the marks of shorelines of the great shallow seas that several times covered the eastern two-thirds of Montana. Through eastern Montana's badlands you'd see eroded rocks shaped by running water and wind erosion. You might visit a mine where a clay called bentonite is being dug from the earth. This clay was laid down millions of years ago when ash from volcanoes in the Cascade Range of Washington and Oregon settled into Montana's shallow prehistoric seas.

In the foothills and valleys you might notice long mounds or hills called moraines, deposited by glaciers as they slowly retreated northward across the plains. As you reach the Rocky Mountains, you might observe a road here and another there corkscrewing to the top of a bare brown hill where the earth is scarred by a gold mine. And when you cross the high mountain valley of Elk Park and drop into Butte, you see what was once one of the largest open-pit copper mines in the world, a huge hole now abandoned.

Montana holds deposits of most of the minerals known in the world. Many of these minerals are found in large amounts (see the map on page 8 for their locations). How did they get deposited where they are? Whether they were found in a narrow rock-lined canyon or beneath a sagebrush-covered prairie, these minerals are the results of certain events in the land's geologic history. It's a long story—a very long story that began millions and millions of years ago.

In the beginning there were no mountains in Montana—only swampy plains and seas gradually accumulating mud, sand, and a sort of ooze made up of the earliest primitive plants and animals as they decayed. This material became the sedimentary rocks that underlie Montana today.

More millions of years saw a vast wrinkling and folding of the earth's surface that finally created the ancestral Rocky mountains. But those early mountains were worn away by wind and water, and the products of that erosion were deposited in the surrounding seas.

Next, sand and mud settled out of slow-moving streams that spread across a wide plain between rising mountains to the west and a shallow sea to the east and south of Montana. The climate was warm, and among the streams, trees similar to cyprus and redwood grew in great swamps. Dinosaurs roamed the flood plains; their skeletons have been found in the rocks south of Glendive and elsewhere.

The sand, mud, and decaying parts of plants and animals gradually solidified into layers of sandstone, shale, and limestone from five to ten miles thick. Between Great Falls and Lewistown, peat that gathered in a swamp as large as the Everglades of Florida eventually became the oldest coal deposit in Montana. (Coal miners sometimes find what is called a "coal ball" filled with fossil plants that grew in these swamps, and plant leaf impressions also are found.)

In the western third of Montana, forces that evidently came from the southwest began pushing the layers of sedimentary rock very slowly into great folds. These rock folds, deep within the earth, finally began to crack under the stress, and in some places they began to slide over each

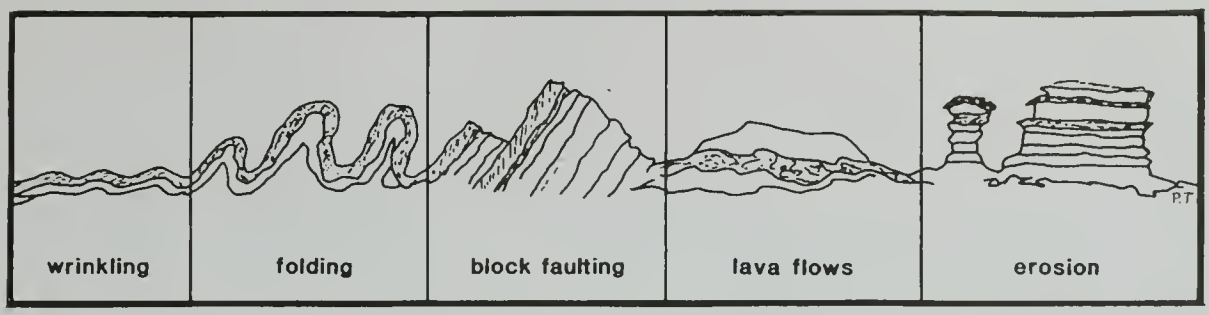

Figure 1. Five Kinds of Mountain Building

other. This process, called thrust faulting, is typical of the Overthrust Belt of western Montana. A relaxing of the pushing (or compression) forces caused block faulting, which combined with thrust faulting and erosion to form most of Montana's western mountains. In many places, erosion has exposed the bare rocks that gave the Rockies their name. In a day's drive in some parts of Montana you can see examples of the kinds of mountain-building shown in figure 1.

Igneous (or volcanic) rocks are prevalent in western Montana and may have mineral deposits in or near them. There are two kinds of volcanic rock—intrusive and extrusive. The first, once melted by intense heat far below the earth's surface, cooled and hardened at varying depths in large masses. During this time, liquids in the crystallizing mass were forced upward into cracks, carrying dissolved minerals with them. When these formations hardened, their folds and crevices held, in some places, quartz veins with rare, but sometimes rich deposits of precious metals. In figure 2, the thick white layer of rock in the outcropping and the thinner ones above it are quartz.

Figure 2. Quartz Outcropping Peggy Todd

The second kind of volcanic rock was extruded, or poured out, over the surface of the earth, and cooled much more rapidly than the rock below the surface. In these rocks, such as andesite or rhyolite, the crystals are much finer-grained.

Many gold and silver mines, as well as zinc, manganese, copper, and lead mines, are located in or near these igneous formations. One of these formations, the Boulder batholith, 50 miles wide and 60 miles long, extends from Butte north and west to Helena. The MacDonald Pass road (US Highway 12) crosses this formation west of Helena. The batholith's jointed and folded ledges can be seen from the interstate highway between Butte and Whitehall. The Idaho batholith, an earlier and larger intrusion, is located mainly in Idaho, but extends from Mineral County near Superior southward, to make up the Bitterroot Range southwest of Missoula. Not all igneous formations are rich in minerals; if the magma or lava that formed them contained no metals of value, none could be deposited.

A third type of rock results when certain conditions cause igneous and sedimentary rocks to change—they then become metamorphic rock. High temperatures and pressure far beneath the earth's surface,

together with the addition or removal of mineral materials, can bring about this change. Some of the oldest rocks in Montana, those in the Ruby Mountains and the Beartooth Plateau, are metamorphic rocks. Marble and slate are metamorphic rocks; talc and garnet are two minerals formed in this process.

Types of Minerals

All minerals can be classified as metals, nonmetals, or fuels. Of the metals, copper, gold, silver, and platinum are Montana's most valuable. Others, such as the chromite found in the Absaroka Range, are also rare throughout the world.

Montana also has plentiful deposits of other minerals. Nonmetals, or industrial minerals (for example, gypsum, marble, vermiculite, and talc) are mined in different parts of the state. Oil or natural gas—fuel minerals—may be pumped out of so-called pockets thousands of feet deep in the earth. The third fuel mineral, coal, has been mined for many years from deposits near the surface in central and eastern Montana.

Metals

The metals that played an important part in Montana's past continue to be important today. Metals have been valued throughout history—they made it possible for humans to till the soil, wage war, and carry their worldly wealth with them as coins or jewelry. The value of metals can change, of course, with events. As a result, Montana's economic health has changed many times as metal values changed.

At the time of the gold rushes in the American West, gold was used like money. A man with a deerskin sack (or poke) of gold dust could buy what he needed. Merchants had gold scales on their counters to weigh out the "dust" in trade for tools or groceries.

The mining strikes that began in the Rocky Mountains in the 1860's were gold and silver discoveries. These metals were often found together. Most of the early prospectors struck placer gold—rarely nuggets, but usually flakes of gold found by washing (or panning) the gravel of creek beds. This gold had eroded out of exposed veins, and because it was heavier than other minerals, had sunk to the creek bottoms and gradually been concentrated in placer deposits.

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ROCKER — a slotted box for washing gold out of gravel or ore. It had curved supports that allowed it to be rocked. The ore was mixed with water and washed over the slots. The flakes of gold, being heavier than water, dropped into a tray below. Rockers were used in one-man operations, and were similar to sluice boxes.

The first recorded gold discovery in Montana was in 1852 on Gold Creek near Garrison. However, it was not until ten years later, as prospectors began to drift from worked-out placer diggings in California and Nevada, that the big strikes took place at Bannack, the first territorial capital, Alder Gulch (Virginia City), Last Chance Gulch (Helena), and many other places in the mineral-rich Rockies.

Among the gold mining districts in Montana, Jardine and its neighboring districts near Yellowstone Park are unique—their deposits of precious metals were formed in an earlier geologic time (Precambrian) than were those elsewhere in Montana. In the Philipsburg mining district, over 80 minerals have been identified. In the Tobacco Root, North Moccasin, Judith, and Little Rocky mountains, there

are mines rich in gold. Some of these ranges contain almost circular mountains called laccoliths, blister-like formations formed when molten rock forced its way, under great pressure, between layers of sedimentary rock.

When the placer gold became scarce, deeper deposits were reached by hard-rock mining, that is, blasting out mineral-bearing rocks or ore. Until the railroads reached western Montana, however, the going was slow. The heavy machinery of the stamp mills used to crush the ore was freighted first by wagon and later by rail. Hard-rock or quartz mining came into wide use when this milling equipment became available. Much of the ore was milled close to the mines to avoid shipping it long distances by wagon. In some ghost towns you can see all that's left of these mills near the entrances to worked-out gold and silver mines (figure 3). From the days of the lone placer miner to the present, one hundred and fifteen years of mining have produced over 1/2 billion dollars' worth of gold and nearly a billion dollars' worth of silver.

Unforeseen changes have recently taken place in gold mining in Montana. Some gold mines that closed down forty years ago have opened again. Today's gold miners have higher gold prices on their side as well as improved technology. Now retrieving even small amounts of gold is profitable with modern equipment and new processes. One experimental way of removing gold from ore, called heap leaching, has been tested near Whitehall and at Landusky. Only the Landusky ore, however, has proven suitable for this process.

Ninety percent of the state's output of all metals came from the deposits at Butte, "the richest hill on earth." All but one-tenth of Montana's copper was mined there. Until 1982, Butte's famed Berkeley Pit ranked third in open-pit copper mining in the United States, fifth in silver production, and thirteenth in gold production. (Early in 1982, the Anaconda Company stopped mining the low-grade ore of the Berkeley Pit. Mining is now limited to molybdenum, copper, and some gold and silver from the East Pit.)

In 1880 when Marcus Daly, later to be known as the "Copper King," bought half interest in a mine called the Anaconda for $15,000, he was fairly sure it contained high-grade copper ore, although it had been a silver mine. By the time the shaft got down to 300 feet, he knew he had struck a rich vein of copper—it was the vast Anaconda lode. The vein of copper in the Anaconda mine was five feet wide, the largest then known in the world. At that time most miners considered copper a "nuisance" metal. But Daly, both shrewd and far-sighted, knew that the growing use of electricity and the telephone meant that copper would be valuable for wiring.

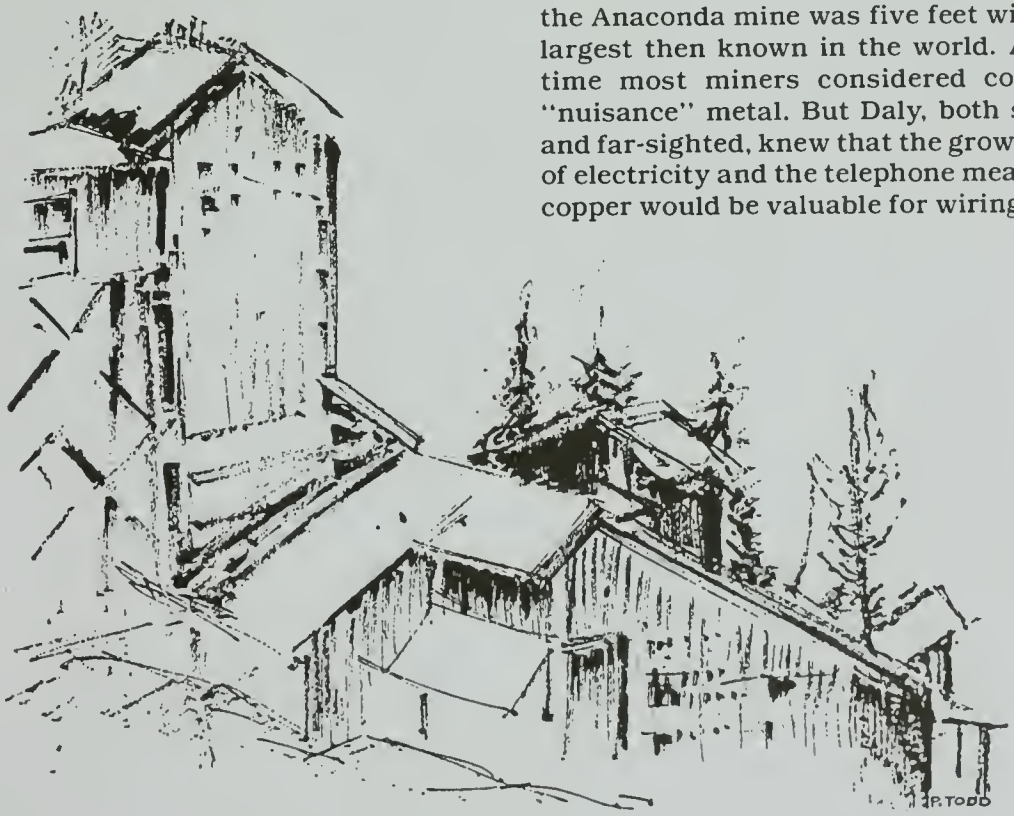

Figure 3. Stamp Mill

Peggy Todd

It was the beginning of boom times for Butte. Before they were through, miners working for Daly, William C. Clark, and James Ben Ali Haggin had dug tunnels under the city that (it was claimed) would have reached from San Francisco to New York City. Every mine was marked at the main shaft (figure 4) by a head frame often called a "gallows frame" because it resembled the framework used for hanging criminals. This frame contained the elevators that carried men and equipment up and down the shaft and ore up from the workings.

A hundred years later, there aren't many gallows frames on the hills of Butte to mark the underground shafts of mines like the Alice, the St. Laurence, the Orphan Girl and the Never Sweat. Butte shifted gears to open-pit mining in 1956, partly because, with modern machinery, it was cheaper than shaft mining. This method mines great quantities of low-grade ore. The value of gold, silver, copper, lead, zinc and other metals mined in Butte has a total value of around $14 billion since mining began in 1863.

Until 1980, two smelters in Anaconda extracted metal from ore mined in Montana. A refinery at Great Falls processed copper from those smelters and from others out of state, but it is now dismantled and the smelters are closed. Inflation and a drop in worldwide copper prices contributed to the shutdown of the Anaconda smelters and the refinery. A lead smelter at East Helena still receives ore and concentrates from the western United States and foreign sources.

Montana mines many other metals besides those found with copper; tungsten, chromium, nickel, and iron are among them. Eighty percent of U.S. chromite, for example, is found in the Stillwater Complex along the Beartooth Mountain front south of Columbus. This very hard, crystalline metal is used to make other metals corrosion-resistant—like your car's chrome trim—and in alloy with other metals. Tungsten, used in machine tool and steel production, was, at one time, open-pit mined in Beaverhead County. Montana has one of only two antimony mines in the United States. This metal, used mostly as a flame retardant, also is used in batteries, ceramics, glass, and in manufacturing chemicals.

Nonmetallic Minerals

Just as useful as metals, in other ways, are Montana's more common industrial or nonmetallic minerals. You could build a house, panel and insulate it, install windows, make a sidewalk, and supply your

Figure 4. Gallows Frames in Butte

Montana Historical Society, Helena

kitchen with cooking pots, using these minerals. You could even line your swimming pool. Montana has plentiful supplies of all the minerals you would need.

Building stone is quarried from several deposits, mostly in the western part of the state. One of these stones, travertine, comes from lime deposits like those around Mammoth Hot Springs in Yellowstone Park. The gray sandstone found in Montana's Rockies can be seen in many of the courthouses around the state. Steps and thresholds that receive a lot of wear are often made from Montana granite.

A large mine in Lincoln County near Libby produces vermiculite for fire-resistant insulation and other uses. Gypsum, which also resists fire and is used to make sheetrock building panels, is mined in Judith Basin County. There are several high-grade deposits of clay, such as those in Cascade and Jefferson counties. Clay is used by local potters, including those who work at the Archie Bray Foundation in Helena. Many years ago, bricks were manufactured at several locations from some local clays. The "Silos," a landmark between Townsend and Helena, were made from Montana brick, as are many buildings in the Deer Lodge valley.

Montana has large deposits of bentonite, a clay-like mineral developed from volcanic ash. Wet bentonite swells to form a water barrier and is used as a reservoir sealer. It is used in oil fields as a drilling mud, and is shipped to the Great Lakes area for use in steel production. Ranchers in Montana use it to seal ditches so they will hold water.

The limestone mentioned earlier is also used as flux in smelting lead or copper. (Flux is a material that fuses with undesirable matter to form a liquid residue.) Dan Morrison, the man who discovered the Lewis and Clark Caverns near Whitehall, was prospecting for limestone when he found these caves, which are now a state park. Two plants, one at Trident, near Three Forks, and the other at Montana City, south of Helena, use local limestone to produce cement.

Talc is another versatile industrial mineral—it was overlooked when early gold hunters came along the Gravelly Range in Madison and Beaverhead counties, but came into demand during World War II. This high-grade talc was used in making ammunition, and is now mined for ceramics, paints, cosmetics, paper manufacturing, and diamond processing. Talc can be turned on a lathe, and when baked, will not shrink or change its shape.

Montana also has its share of gemstones. Sapphires of both gem and industrial grade are often found with gold-bearing quartz. The unusual cornflower-blue sapphires of Yogo Gulch near Lewistown in Judith Basin County have brought over $2 1/2 million. Another well-known gemstone, the Montana moss agate, is found along the Yellowstone River from Livingston to Glendive. Along many rivers, garnets are mixed with sand and gravel. The ruby sandpaper you can buy at the hardware store contains finely ground low-grade garnets. Owners of gem mines often sell specimens, or for a fee, allow visitors to pick through gravel in hope of finding a rough gem. Specimen collectors can find excellent examples of many minerals across Montana (figure 5).

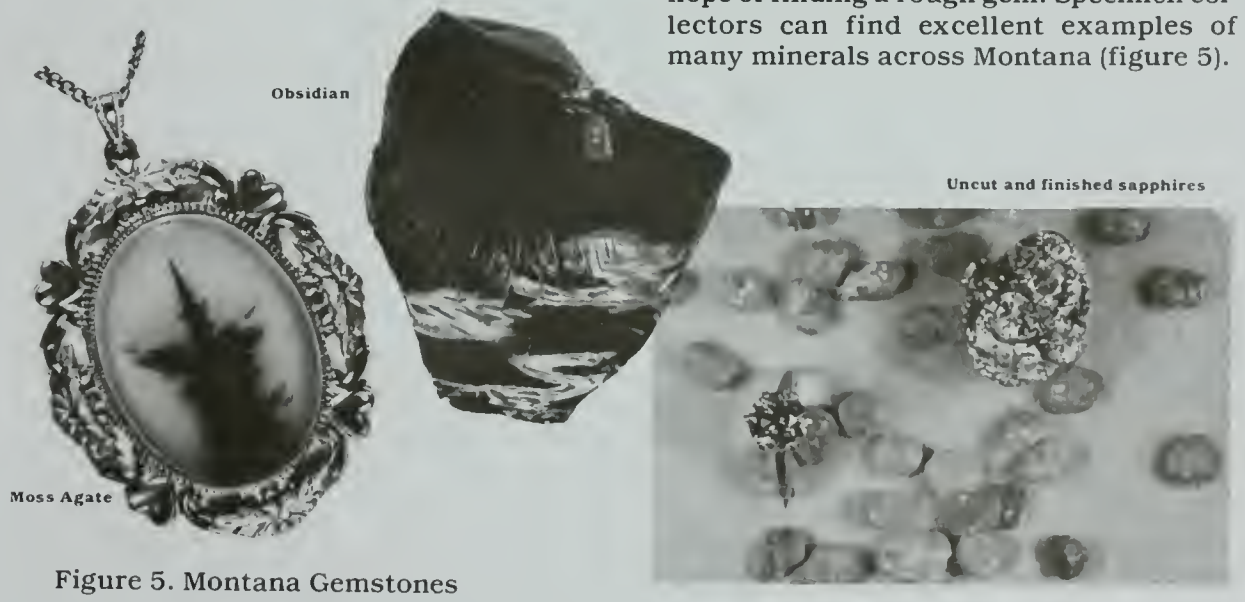

Figure 5. Montana Gemstones and Obsidian

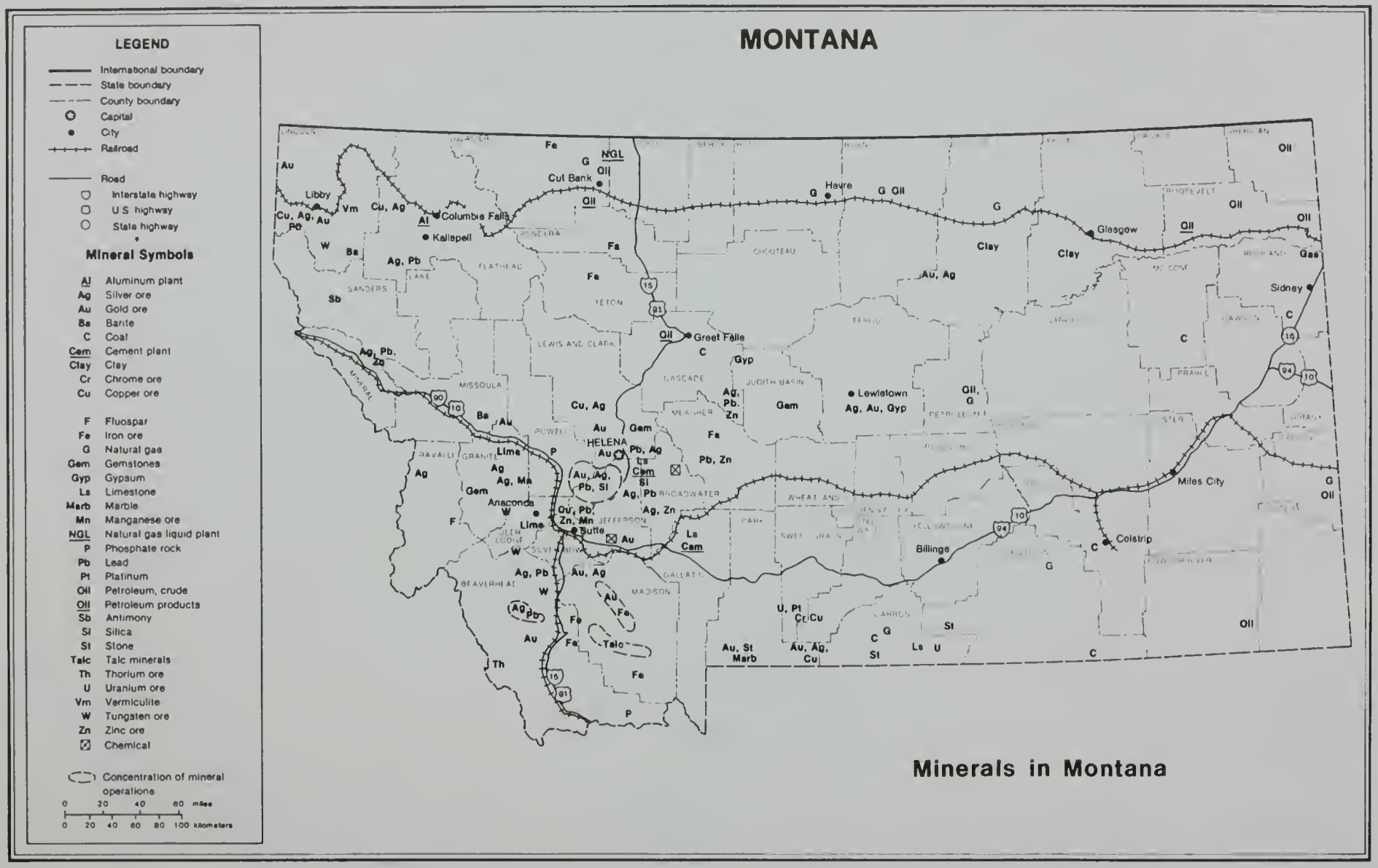

Figure 6. Minerals in Montana

Obsidian breaks along curved or conchoidal (shell-like) fracture lines. By striking the edge of a piece of obsidian with another rock, a series of small chips can be removed, leaving a very sharp edge. Indians made points for spears, arrows, and fishhooks, as well as awls for working leather.

In places molten lava erupting on the surface cooled rapidly, like the so-called Glass Hill (or Obsidian Cliff) north of Norris Junction in Yellowstone Park. Indians found obsidian in these areas, and chipped this volcanic glass into barbed points for arrows and spears, and for scrapers and other tools. (They also carved a clay-like stone found on Pipestone Pass south of Butte into ceremonial pipes.)

Among the other nonmetallic minerals is phosphate rock, which is mined for fertilizer in Powell County. Also, sand and gravel deposits are numerous throughout the state. Many of them were left behind as glaciers receded northward, and are often well sorted by water along the streambeds. Road builders in Montana seldom have difficulty finding high-quality roadbed and surfacing materials close at hand.

Fuels—Coal, Oil, and Gas

The prairies and bluffs of eastern Montana cover one of the most important coal deposits in the United States, the Fort Union Formation. Here the coal lies in almost horizontal beds between layers of sandstone, siltstone, and shale. The oldest deposits were laid down around 60 million years ago at a time when subtropical forests and swamps covered the area. The Fort Union Formation includes three layers, or members—the Tulloch, which is the oldest, the softer middle layer called the Lebo, and the Tongue River Member, the most recent. This top layer can be seen in the cliffs in the area where thick reddish bands of clinker were left when coal beds burned at some time in the past.

Three qualities of coal are found in Montana's coal fields—bituminous, subbituminous, and lignite (figure 7). Most coal mined in the state is subbituminous with a low sulfur content; it burns without leaving much ash, and makes a fairly good fuel. It doesn't give as much heat as the hard anthracite coal mined in the eastern United States. However, Montana coal is plentiful and can be mined without underground digging.

Most of Montana's coal lies close enough to the earth's surface so that it can be mined by strip (or surface) mining—that is, removing the soil and rock that lies on top of the deposits (called overburden), and then removing the coal. After the overlying material is loosened by blasting, it is removed by giant electric shovels (or draglines) and stockpiled. The coal, also blasted loose, is taken out in sections, and the overburden is then replaced in the hole or backfilled in the mine behind the open-cut operation.

Montana law requires that coal companies restore the areas where mining has been done; the Montana Department of State Lands oversees reclamation, as does the Federal Office of Surface Mining. Coal companies operating in Montana must post a bond for reclamation, and may not recover this money for ten years. The process of reclamation attempts to make the land look much as it did before mining, and to restore most of its productivity.

Reclamation starts with mining—at that time the topsoil and the subsoil are separated and stockpiled. After the coal has been removed, the earth is replaced, with the topsoil making the top layer, and is graded so it blends with the surrounding landscape. It is then seeded with a combination of grasses, usually those native to the region. Sometimes woody shrubs and small trees are also planted.

The Tongue River Formation contains some of the most productive coal mines in North America. The Decker coal field alone

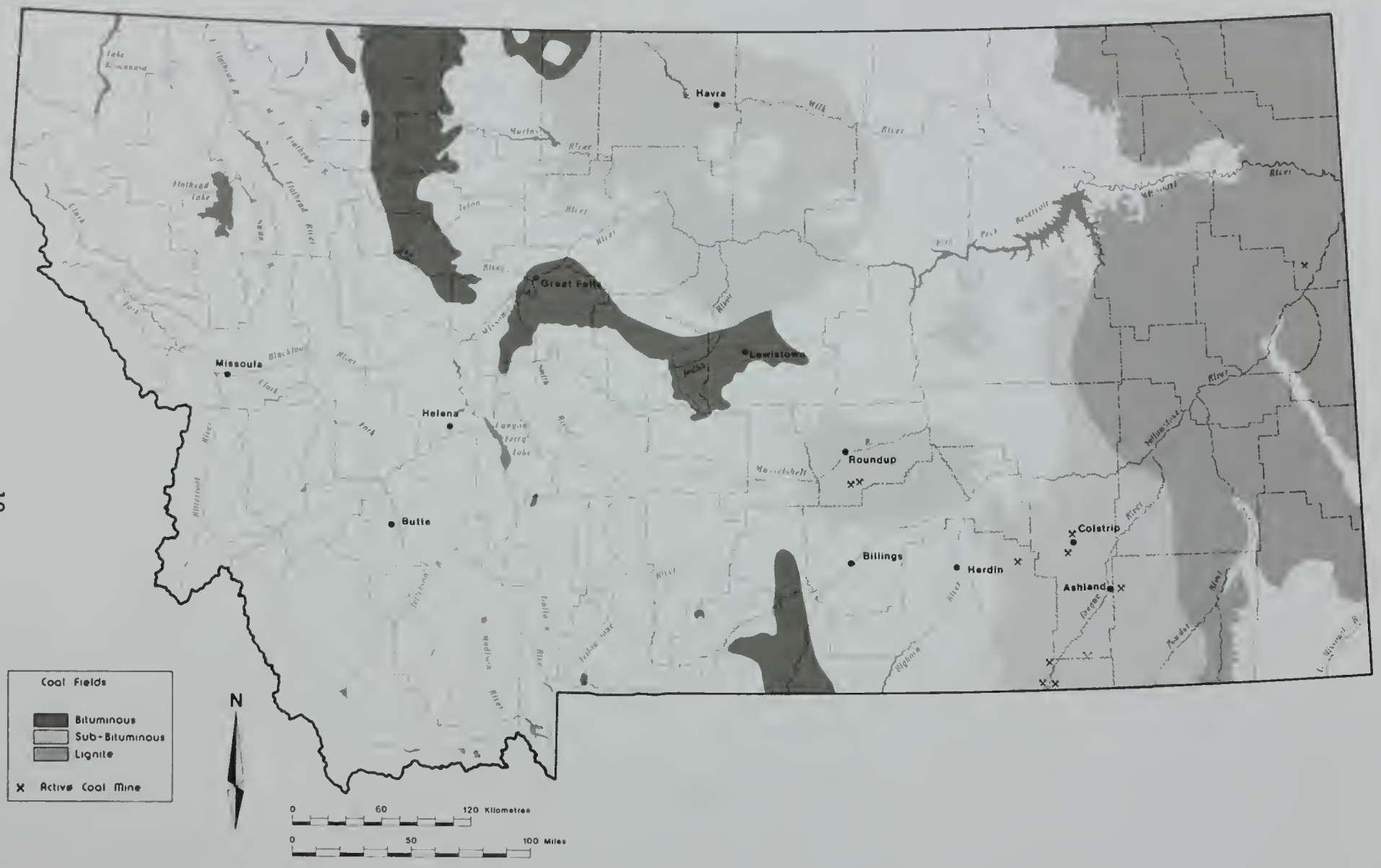

Figure 7. Coal Fields in Montana

has deposits of 5,499 million tons. About 85 percent of this subbituminous coal can be recovered by methods used at present. The main bed is 80 feet thick, with other seams from 32 to 55 feet thick. Mines at Colstrip (the oldest strip mining area in the state), Coal Creek, Ashland, and Sarpy Creek produce subbituminous coal, as do two mines south of Roundup in the Bull Mountain field. The only mine in the state producing lignite coal is the Savage Mine in Richland County.

In addition to these active mines, Montana also has huge reserves of coal, that is, known deposits that have not been mined. The Montana Bureau of Mines and Geology has conservatively estimated over 50 billion tons could be surface mined. A 1979 U.S. Geological Survey report estimated that 102 billion tons could be mined profitably. However, it probably would not be practical to try to recover all this coal now, since the U.S. market uses only about 700 million tons in a year.

Oil often occurs in the same areas as coal; Montana ranks among the top 15 states in oil production, with 30 million barrels produced annually. In addition, Montana natural gas deposits produce more than 33 billion cubic feet of gas each year. Three fields in central and north central Montana produce about 40 percent of all the natural gas recovered in the state.

More recently, exploration has shown that massive amounts of gas and oil may be located in what is called the "Overthrust Belt." As its name suggests, the belt marks a line where portions of the earth's crust slid over each other during the last great mountain-building period in the western United States. This belt snakes down the eastern side of Montana's Rocky Mountains, curves westward through Beaverhead County in southwestern Montana, and turns east again as it enters Idaho and Wyoming.

Two refineries at Billings and one at Laurel produce 40,000-50,000 barrels of oil per day, and smaller ones at Cutbank, Wolf Point, and Great Falls have outputs under 10,000 barrels per day. Much of the crude oil refined in Montana comes by pipeline from Wyoming. Canada trades an equal value of crude oil for the refined product.

The rising costs of imported petroleum, together with unsettled conditions in the oil-rich Far East, have made Americans look closely at their own fuel sources. Exploration for new oil and gas deposits in the United States has grown dramatically in the past decade, and new methods of extracting these fuels are being rapidly developed. Coal mining has once again become profitable. In 1980, coal produced from mines in Montana totalled 29.8 million tons. Most Montana coal is being mined to fuel electrical power plants out of state. Four are in operation in the state; others using synthetic fuels made from coal and oil shale may be built in the near future. The proposed magnetohydrodynamics (MHD)plant in Butte is intended to use coal converted to a super-hot gas.

MHD is a complex process that might be outlined as follows:

Powdered coal is burned in a chamber; the gases that result from this combustion are fed through a nozzle at supersonic speed between magnets and produce electric current that is then drawn off by electrodes. Any kind of fossil fuel can be used. The super-hot gas works somewhat like the rotating copper coils in an electrical generator.

Issues

Montana is historically a "resource" state—she has provided minerals, lumber, and agricultural products to be processed or refined elsewhere. Often Montana benefitted little in the exchange of a product for a paycheck. Some of our current problems in the mineral industry result from Montana's position as a supplier of raw materials.

1. Water is needed for mineral development, but agriculture needs water, too; so do our cities and towns, and other industries. How do we decide who gets the water? Should it go to the highest bidder? How do we set priorities?

2. Boom or bust—should a company be responsible for its former employees' welfare after mining or processing stops? What can be done to make the transition easier? (It has been suggested that resources industries put some of their profits into a "superpool"—a fund that would be available when and where needed.)
3. How much exploration for minerals should be allowed in wilderness areas like the Bob Marshall?
4. What effect will increased coal development have on our future, both economic and environmental? Montana's coal severance tax is the nation's highest—are there better ways to control our share of this nonrenewable resource?

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The Montana Department of Natural Resources and Conservation has had many requests for information about the minerals, water, forests, and other resources in Montana. This booklet is one of a series presented to answer some of those questions and to stimulate an interest in the natural resources of Montana. The University of Montana cooperated with DNRC in preparing the series which was financed in part by a federal grant made under Title I of the Higher Education Act of 1965.

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